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ESTIMATION OF POSSIBILITY OF USAGE OF QUASIAZEOTROPIC MIXTURE R134a/R152a IN REFRIGERATING ENGINEERING

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ABSTRACT

Theoretical and experimental studies for estimating an expedience of use of quasiazeotropic mixture R134a/R152a (0.8/0.2 mol/mol) in refrigerating equipment were carried out. The problems of compressor oil in energy efficiency of refrigerating equipment were considered. It has shown that the inflammable mixture R134a/R152a (0.8/0.2 mol/mol) has a number of sufficient thermodynamic and operation advantages over refrigerants R134a and R401A.

INTRODUCTION

Optimal selection of new working substances for refrigerating equipment is a difficult scientific and technological problem. To do it, there is a necessity of taking into account a whole number of contradicting ecological, toxicological, and economical, and technological, and thermodynamic factors. However, energy efficiency of new generation refrigerating equipment must be a main criterion for estimating prospects of new ecologically safe refrigerants.

In turn, energy efficiency depends both on selecting refrigerant and optimal choice of compressor oil. Existence of the oil in the system effect sufficiently on thermodynamic properties of the working substance shifting the points of the refrigerating cycle [1, 2].

The Ukraine takes measures for turning on ozone-safe refrigerants. At the beginning of the 90th the refrigerant R134a pretended to be an indisputable alternative to R12. However, numerous investigations and accumulated experience of the operation and exploitation of the new generation refrigerating equipment have shown that the refrigerant R134a did not ensure a higher energy efficiency compared with R12. Besides, R134a has a high value of Global Warming Potential (GWP). Additional problems arising with producing and operating refrigeration engineering were connected with high hydroscopicity of fairly expensive polyol ester (POE) oils. Presence of inadmissible moisture in the refrigerating storage leads to POE oil hydrolysis. These chemical process cause a growth of corrosion activity of the working substance, and increase a compressor units wear, and rise a possibility of corking throttles. Such features of using of new POE oils in mixtures with R134a make difficult technological process of refrigerating equipment assembling, and rise a cost of its operation.

Results of studies obtained in the Odessa State Academy of Refrigeration [3, 4] have shown that using of quasiazeotropic mixture R134a/R152a (0.8/0.2 mol/mol) will remove a sufficient part of shortcomings typical for the working substance R134a/POE oil. Mixture refrigerant

R134a/R152a (0.8/0.2 mol/mol) became interest years ago [5-7]. Its thermodynamic properties are well known [5-7], its inflammability [5] and thermodynamic properties of solution refrigerant/oil have been studied [3].

RESULTS

Information about caloric properties of solutions refrigerant/oil is necessary for taking into account an effect of oil admixtures on energy efficiency of refrigerating cycle. Existing methods of calculation are based on the use of various equations of state [8]. As the analysis has shown, these equations can not ensure a qualitative description of caloric properties of the mixture refrigerant/oil because of high error of phase equilibrium description [8]. So, at restricted volume of experimental information, it is expedient to use more pragmatic methods based on direct using of data on phase equilibrium in the mixture refrigerant/oil. Such method of phase equilibrium description and calculation of caloric properties has been used in the works [2, 9].

Enthalpy and heat of evaporation of mixture of the refrigerant R134a/R152a (0.8/0.2 mol/mol) with synthetic oil XΦ22c-16 and the refrigerant R134a with the oils Castrol Icematic SW-22 and Mobil Arctic 22 were calculated in the frames of the above-mentioned method. Compressor oil XΦ22c-16, used in refrigerating equipment with R22, is widely spread over the Union of Independent States (UIS). Results of previously published works [3, 7, 10] were used as an initial information for calculation of caloric properties.

While calculating the refrigerating cycle with the heat regeneration, it must be started from that the partial oil pressure in vapor phase of the mixture is extremely low, and oil concentration at condenser outlet is only 0.15-0.30% [11]. After throttling the solution refrigerant foil enters the evaporator where it is mixed up with the boiling working substance. Since boiling takes place at however, compared with condensation, parameters (P_o. T_o), then oil concentration in the working substance grows up X_o=8-16% [11]. More precise data on the oil concentration in the evaporator can be obtained only with real tests of the equipment, the information about phase equilibrium in mixtures refrigerant/oil granted.

Estimation of oil admixture effect has been made for refrigerating cycles at parameters, regulated by State Standard (GOST) 17008-85, with the method published in the work [11]:

- temperature of refrigerant boiling in evaporator T_o=243 K and 253 K;
- temperature of refrigerant condensation T_C=328 K;
- temperature of refrigerant at compressor inlet was equal to 305 K;
- temperature of overcooling was equal to 305 K.

The values of specific refrigerating capacity q_o, and heat of condensation q_C, and work of isoentropic compression l, and refrigerating coefficient ε for three working substances at oil concentration at condenser inlet X_o=0%, and 0.15% and 0.3% were calculated and given in Table 1.

These results show on certain thermodynamic advantages of mixture refrigerant R134a/R152a(0.8/0.2mol/mol) with the oil XΦ22c-16 over the most often used working substances based R134a. The parameters of the refrigerating cycles being given, the mixture refrigerant R134a/R152a(0.8/0.2mol/mol) has the value of specific refrigerating capacity by 10%, and the value of refrigerating coefficient by 5% higher.

Table 1.

Calculated values of energy characteristics of refrigerating cycles for several working substances

	R134a/152a(0.8/0.2mol/mol) /XΦ22c-16						R134a		R134a /Mobil Eal Arctic22				R134a /Castrol Icematic SW22			
X_o	0%		8%		16%		0%		8%		16%		8%		16%	
X_K	0%		0.15%		0.3%		0%		0.15%		0.3%		0.15%		0.3%	
T_o,K	243	253	243	253	243	253	243	253	243	253	243	253	243	253	243	253
q_o, kJ/kg	146.2	152.7	141.5	148.6	141.2	147.7	135.3	141.6	131.8	138.2	131.2	137.7	131.7	138.1	131.1	137.5
q_C, kJ/kg	246.8	230.7	247.2	230.9	249.7	231.5	229.2	213.4	230.4	215.7	231.4	215.7	229.1	213.9	229.5	213.4
l, kJ/kg	81.1	65.8	82.3	66.9	85.5	68.3	78.1	63.2	79.8	65.9	81.5	66.4	78.6	64.2	79.7	64.8
ε	1.80	2.32	1.72	2.22	1.65	2.16	1.73	2.24	1.65	2.1	1.61	2.07	1.68	2.15	1.64	2.12

Results of operation tests (see Table 2) support a positive estimation of prospects of using of quasiazeotropic mixture R134a/R152a (0.8/0.2mol/mol). The refrigerating hermetic with air-cooled condenser Bcэ800(2)2M was an object for the study. The unit has been filled by alkyl benzene lubricant Zerol, 1.4 kg of mass, and a refrigerant, 2 kg of mass. As to four parameters measured in the tests, the refrigerant R134a/R152a (0.8/0.2mol/mol) has essential advantages compared with R134a and R401A, and yields to R12 in energy efficiency only at low temperatures of boiling in the evaporator.

This refrigerant has the value of Global Warming Potential considerably lower than that of R134a, it is soluble in serially produced cheap oils (synthetic oil XΦ22c-16 and alkyl benzene Zerol), and provides higher energy efficiency of refrigerating equipment.

The mixture R134a/R152a (0.8/0.2mol/mol) just as R401A, can be used for retrofitting refrigerating equipment with carried out electric motor. Thermodynamic properties and operation characteristics of the refrigerant R401A yields somewhat to those of quasiazeotropic mixture R134a/R152a (0.8/0.2mol/mol).

In the first place, R401A has very wide difference of boiling and condensation temperatures ΔT_{glide}=6-7 K. In hampers the procedure of refilling refrigerating storage and may lead to the breakdown of normal cooling regimes. In the second place, R401A has comparably high ozone depletion potential ODP=0.037 and yields to the mixture R134a/R152a (0.8/0.2mol/mol) in energy efficiency

Process of regenerative heat exchange during oil circulating along the contour of refrigerating storage differs essentially from that with a pure refrigerant. In fact, not a heating of pure vapour takes place in the regenerator, but a process of finishing evaporation at growing vapour temperature. The start of regeneration is no longer fixed by the boundary curve, as is for a pure refrigerant. This process depends on the interval of degassing in the evaporator adopted practically or when making calculations.

Table 2.

Results of compressor BCэ8.00(2)2M* testing

Parameters	Refrigerants			
	R134a/R152a 0.8/0.2 mol/mol	R12	R134a	R401A
t_o=-5°C, t_a=20°C, t_i=20°C				
1. Refrigerating capacity, W	1194.5	1150.8	1103.4	1120.6
2. Consumed power, W	548.5	565.5	567	576
3. Specific refrigerating capacity, W/W	2.18	2.03	1.95	1.94
4. Temperature of condensation, °C	37.9	42	41.5	42.2
t_o=-15°C, t_a=20°C, t_i=20°C				
1. Refrigerating capacity, W	785.3	806.1	739	745
2. Consumed power, W	435	470.5	444.5	450
3. Specific refrigerating capacity, W/W	1.805	1.71	1.66	1.66
4. Temperature of condensation, °C	31.2	35.6	34.8	35.5
t_o=-25°C, t_a=20°C, t_i=20°C				
1. Refrigerating capacity, W	440.1	514.6	392.9	410
2. Consumed power, W	345.5	365.5	340.5	347.5
3. Specific refrigerating capacity, W/W	1.27	1.4	1.15	1.18
4. Temperature of condensation, °C	26.9	29.8	28.8	30.4

The following definitions were used in Table 2: t_o stands for boiling temperature in the evaporator; t_a=20 °C stands for temperature of air around the unit (compressor and condenser); t_i=20 °C stands for temperature of the refrigerant at compressor inlet.

Results of the studies of regenerative heat exchange influence on energy characteristics of the cycle obtained in the case of working substance R134a/R152a (0.8/0.2 mol/mol) when the temperature of condensation T_C=300 K and oil concentrations at condenser outlet X_C=0.094 and 0.19% were illustrated by Pic. 1-4.

Results of calculation lead to the following conclusions:

1. Presence of refrigerating oil in working substance leads to lowering specific refrigerating capacity by 2-3%.
2. Since saturation vapour pressure of the mixture refrigerant/oil is lower than pure refrigerant temperature at given temperature in the evaporator, then isentropic work of compression grows by approximately 10-12%.
3. In the case of absence of regenerative heat exchange the growing of oil concentration in the evaporator up to 10% leads to lowering refrigeration COP - ε by 13-16%.
4. The use of regenerative heat exchange permits to retain boiling temperature practically constant with narrowing down the degassing interval in the evaporator without sharp lowering of useful refrigerating capacity of the refrigerant.

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CONCLUSION

It was shown that compressor oil admixtures in refrigerant vary its thermodynamic properties essentially. It leads to shifting points of refrigerating cycle and lowering refrigeration COP. The use of regenerative heat exchange lowers negative influence of oil admixtures in the refrigerant. Inflammable quasiazeotropic mixture R134a/R152a (0.8/0.2 mol/mol) has a number of essential thermodynamic and advantages over refrigerants R134a and R401A.

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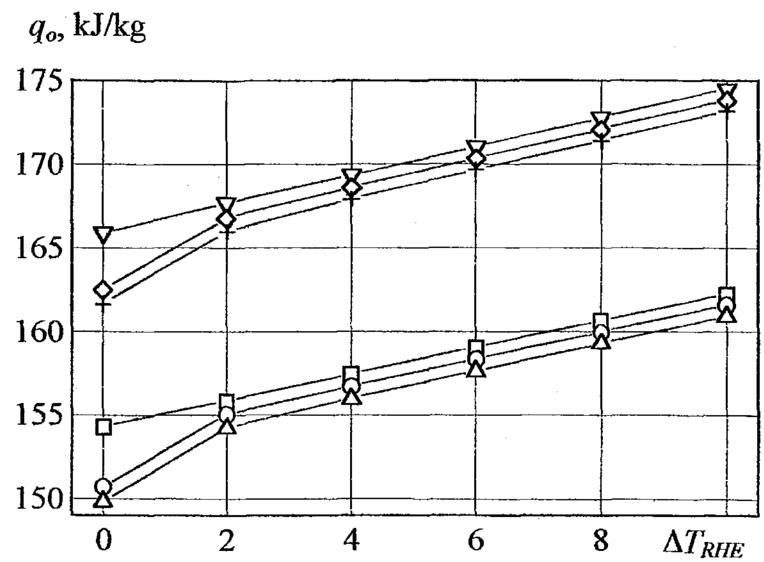
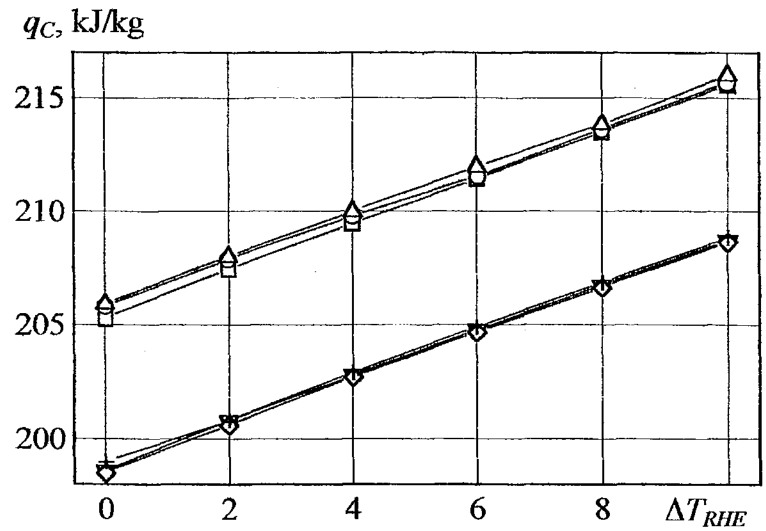


Pic. 1. Dependence of specific refrigerating capacity by regenerative heat exchange value ΔT_{RHE} of working substance R134a/R152a (0.8/02 mol/mol)/XΦ22c-16

T_o=240 K: □ - X_o=0%, ○ - X_o=5%, Δ - X_o=10%

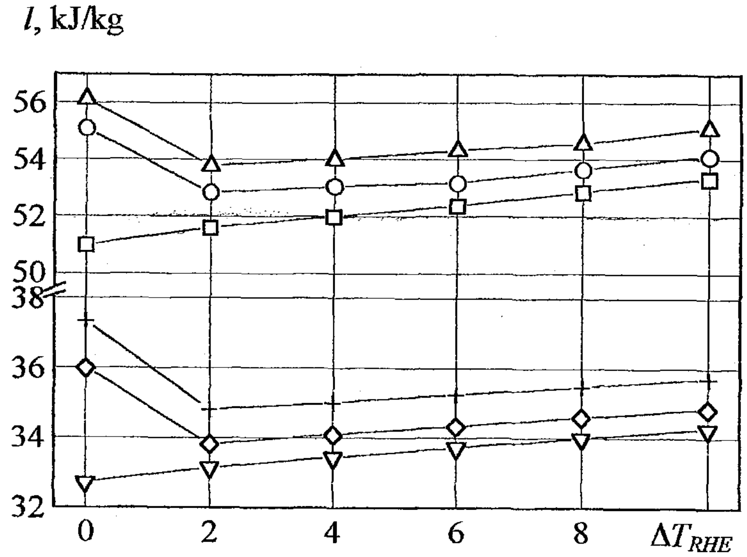
T_o=258 K: ∇ - X_o=0%, ◇ - X_o=5%, + - X_o=10%



Pic. 2. Dependence of heat condensation by regenerative heat exchange value ΔT_{RHE} of working substance R134a/R152a (0.8/02 mol/mol)/XΦ22c-16

T_o=240 K: □ - X_o=0%, ○ - X_o=5%, Δ - X_o=10%

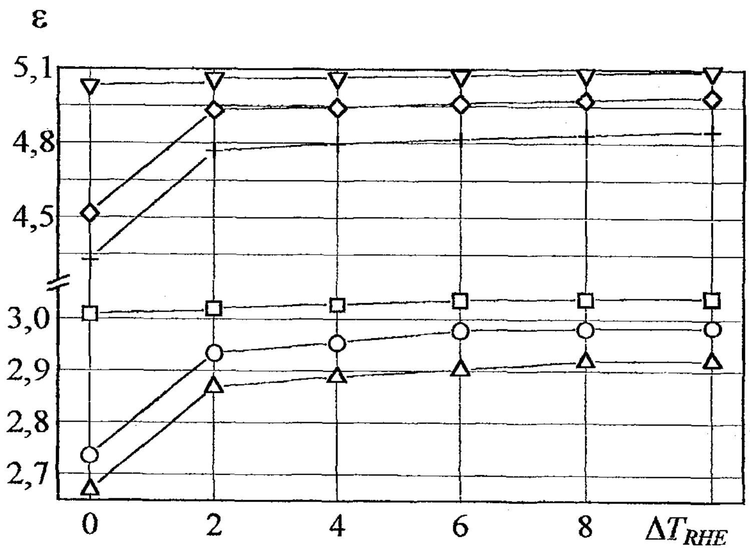
T_o=258 K: ∇ - X_o=0%, ◇ - X_o=5%, + - X_o=10%



Pic. 3. Dependence of adiabatic work of refrigerating cycle by regenerative heat exchange value ΔT_{RHE} of working substance R134a/R152a (0.8/02 mol/mol)/XΦ22c-16

T_o=240 K: □ - X_o=0%, ○ - X_o=5%, Δ - X_o=10%

T_o=258 K: ∇ - X_o=0%, ◇ - X_o=5%, + - X_o=10%



Pic. 4. Dependence of refrigerating coefficient by regenerative heat exchange value ΔT_{RHE} of working substance R134a/R152a (0.8/02 mol/mol)/XΦ22c-16

T_o=240 K: □ - X_o=0%, ○ - X_o=5%, Δ - X_o=10%

T_o=258 K: ∇ - X_o=0%, ◇ - X_o=5%, + - X_o=10%